the requirement for power duty cycling (**Section E.2.6**). **Section F.3 describes science impacts on mission operations. Section F.14 provides more detail on mission design.**

To optimize data quality and greatly enhance scientific return, the SMART payload will generate two science data streams, Survey (with a Slow and Fast mode) and Burst. Burst data are high-time resolution, piecewise continuous data sets that are selected by either an on-board trigger system or time-tagged command (see **Table E-2**).

The instruments will be in Slow Survey mode when the spacecraft are ***not*** in or near targeted regions of scientific interest (determined by orbital phase and time-tagged command). During such times the instruments transfer less than maximum data rates to the CIDP. As the spacecraft enter scientifically targeted regions, they are configured into Fast Survey mode to acquire a full data set at moderate time resolution to determine the context of the targeted region. In Fast Survey mode, all instruments provide burst data to the CIDP, but the data are not necessarily retained.

The burst data scheme, which implements simultaneous capture of high-resolution particle and wave data, works as follows. Each of the fields and particle instruments supplies a continuous stream of burst data to the CIDP, where it is directed into two or more buffers. When a trigger occurs, i.e., during an event of scientific interest, the data are captured for transfer to the spacecraft, including data acquired prior to the trigger. The data are compressed and transferred from the CIDP to the spacecraft recorder at a much slower rate (~100 kbit/s). This scheme focuses data collection on the most interesting parts of the orbit and optimizes the 2-Gbit on-board storage supplied by the spacecraft.

The trigger system is key to a successful unified burst system. Employing a system designed after that used on FAST (R. Ergun, designer), each of the instruments creates a composite, low-rate stream of "trigger" data continuously fed to the CIDP. Using several algorithms, each with a specific scientific focus, the

Table E-2. (revised) ***SMART instrument telemetry data rates***

Instrument	Instrument Data Rate Allocation to CIDP (kb/s)			CIDP Lossless Compression Factor			CIDP Data (kb/s)		
	Slow Survey	Fast Survey	Burst	Slow Survey	Fast Survey	Burst	Slow Survey	Fast Survey	Burst
Fast Plasma - Electrons	0.13	4.10[a]	700.00[c]	NA	NA	NA	0.13	4.10	700.00
Fast Plasma - Ions	0.13	4.10[a]	100.00[b]	NA	NA	NA	0.13	4.10	66.67
Fields	0.80	8.00[d]	796.00[e]	1.50	1.50	1.50	0.53	5.33	530.67
Ion Composition	0.00	2.80	60.00	1.50	1.50	1.50	0.00	1.87	40.00
Energetic Particles	0.00	2.00	36.00	1.50	1.50	1.50	0.00	1.33	24.00
Trigger	0.00	0.25	0.00	1.00	1.00	1.00	0.00	0.25	0.00
Housekeeping	0.50	0.50	0.00	1.00	1.00	1.00	0.50	0.50	0.00
Total Rate	1.06	21.24	1,692.00				0.79	16.98	1394.67
Duty Cycle[f]	60%	40%	1.22%				60%	40%	1.22%
Orbit Averaged Rate	0.63	8.50	20.64				0.42	5.70	17.03
						Daily Stored Data Volume (Mb):	36.29	492.48	1471.23

a) 20^ox20^o, 64-energy electron and ion distributions at 12 second resolution.
b) 10^ox10^o, 64-energy distributions. Sub-sampled distributions (32 Energy at 20^ox20^o) at 63 ms resolution. Full ions 500 ms resolution.
c) 10^ox45^o, 16-energy electron distributions at 8 ms resolution. 10^ox11.3^o at 25 ms resolution.
d) 32 vectors/s E and B, 12 s resolution on spectra.
e) 1 ms on E, 0.1 s resolution on spectra. Includes 63 µs resolution wave forms and 4 µs wave forms at lower duty cycle.
f) 1.22% burst duty cycle provides 17.5 minutes of burst data per day.

CIDP decides when to retain burst data, which buffers to transmit, and which to overwrite. In addition to spacecraft-wide bursts, the trigger system is designed to generate ***mission-wide bursts***, implemented on several levels: (1) time-tagged burst captures can be forced by orbital position (such as on Cluster II; IRAS not required); (2) the spacecraft will have common periods when burst may occur in order to maximize overlap of burst captures (IRAS not required); and (3) the spacecraft can all acquire burst data upon receiving a trigger from any of the other spacecraft (IRAS required). **Table E-2** displays the data strategy on a single spacecraft. In this table, we assume a 2 Gbit/day volume as specified in the AO for the later phases. However, the data system can be better optimized if the CIDP could participate in management of the spacecraft memory. We propose to study an optimized data system in phase A.

We have developed a set of science-based burst mode criteria. These criteria have been derived from our Cluster-based studies, as well as from theoretical insight into the reconnection process itself.

Figure E-23 shows an example of Cluster observations of the nightside reconnection region. The Cluster observations indicate the presence of strong electron flux anisotropies in a region of enhanced electric fields and current densities. In addition, Geotail and Cluster observations during similar events indicate the presence of ion flow reversals, energetic particle streaming, and, at

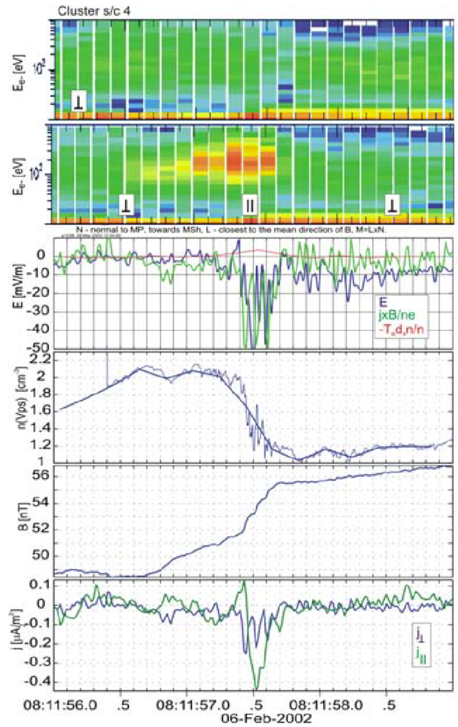

Figure E-23. ***Cluster observation of the nightside reconnection region (from Andre et al., 2003). The top panels display electron fluxes, the third panel shows the electric field (blue), the electron pressure gradient (red), and the Hall electric field (green). The fourth and fifth panels show plasma density and magnetic field magnitude, respectively. The fifth panel displays current densities parallel and perpendicular to the magnetic field, as determined by the curl of the magnetic field.***

Table E-3. ***Physical burst mode triggers. The columns describe, from left to right: The physical phenomenon used as trigger, the trigger criterion for the magnetopause, the trigger criterion for the magnetotail, usability without any additional processing and infrastructure, usability with look direction knowledge. Here B_i denotes B in the s/c spin plane, and B_z the spin axis component of B.***

Physical signature	Value/criterion Magnetopause	Value/criterion Magnetotail	Usable w/o additional processing/infrastructure	Usable with knowledge of look direction
Ion flow reversals	delta v=100km/s in delta t = 1min, front-back asymmetry>100%	delta v=400km/s in delta t = 1min, front-back asymmetry>100%	No	Front-to-back ratios
Large delta B_i, delta B_z	delta B_n=2nT in delta t=1min for FTEs	delta B_n=10nT in delta t=1min	Yes (magnetotail only)	
Large E	E>5mV/m	E>10mV/m	Yes	
Large electron currents	j_e>150nA/m^2, front-back asymmetry>100%	j_e>150nA/m^2, front-back asymmetry>100%	No	Front-to-back ratios
Superthermal electron/ion beams	front-back asymmetry>100%	front-back asymmetry>100%	No	Front-to-back ratios
$E_{\|\|}$	$E_{\|\|}$>5mV/m	$E_{\|\|}$>10mV/m	Yes	

the magnetopause, the presence of parallel electric fields.

The science-based burst mode trigger criteria are summarized in Table E-3. The table shows that a number of criteria can be tested without any additional on-board processing. Specific examples are the magnitude of the electric field and the magnitude of the parallel component of the electric field. For the magnetosphere, the direction of the magnetic field component normal to the current sheet is essentially identical to the spin axes of the four spacecraft. Using look-direction knowledge from our plasma instruments, we will add triggers based on directional flux anisotropies ("front-to-back ratios") in the main current direction for the electrons, or along magnetopause and magnetotail current sheets for ions and energetic particles. We have designed algorithms to generate weighted sums of these trigger criteria to generate spacecraft triggers and weighted averages across the constellation to calculate cluster-wide burst mode triggers.

E.4 Science Team

The SMART science team comprises many of the world's experts on reconnection theory and observations. It is a team of experimentalists who develop, test, and calibrate the instruments and theory and modeling personnel working together to complete the science objectives. The updated science team information is shown in **Table E-4**. Listed are the science team members and their role in SMART data analysis, interpretation, and archiving.

E.5 Data Collection, Analysis, Distribution and Archiving

E.5.1 Data Flow

The team is committed to making the data from this mission available to the entire scientific community as quickly as possible, and to sharing educational data products and information with the public in a timely and appealing manner. The SMART data processing plan combines distributed processing at the instrument Co-I sites with rapid production of merged data products at a central science data center, where the full data set will be archived and accessible on-line. **Figure E-24** illustrates the flow of data and data products. **Table E-4** lists the responsibilities for data product generation and dissemination. **Details of science data analysis methods and tools can be found in Section F.10.**

After each ground station contact, the Science Operations Center (SOC) will acquire all of the telemetry frames containing instrument data returned from the spacecraft, along with appropriate status and ancillary information. The SOC will perform Level-0 processing on these data, dividing the telemetry data streams into sets of packets. The packet sets will then be processed using software provided by LANL and the investigator teams to form Level-1 data and quick-look products to monitor state-of-health and to support operations. These quick-look products will be stored on a server within the SOC and will be accessible to the entire science community via the Internet. Within six hours of ground receipt, the SOC will transfer Level-1 processed data to the SMART Science Data Center (SDC) located at LANL. The SOC will also maintain a database of the Level-0 and Level-1 data throughout the mission.

Within one day of acquisition, the Level-1 science data will be passed from the SDC to each of the instrument co-investigator institutions for Level-2 analysis. Each such institution will then return geophysically meaningful Level-2 data for their instrument to the SDC, based on best-current calibration factors and analysis routines. At the SDC the instrument-specific data products will be combined into Mission Level Data (MLD) products, resulting in a Level 3 database for archiving at the SDC and for distribution to Co-I institutions, the NSSDC and via the Web to the scientific community and the public.

E.5.2 Science Operations Center

Section F.11 describes the SMART suite operations plan in detail. The SOC, which will occupy a portion of the LASP operations center, will be staffed by members of the LASP Space Flight Operations Team (SFOT), which currently consists of 19 professionals and 23 students of the University. Students will be involved in all SOC activities, working closely with the professionals, and will undergo an intensive summer-long training course, testing, and certification. Many of the SOC functions will be performed using existing software, and LASP has the experts to tailor the software for